



MUR-8577US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Michael Russel : Art Unit: 3671
Serial No.: 09/931,552 : Examiner:
Filed: August 16, 2001 :
FOR: DETECTOR ASSEMBLIES AND :
METHODS

CLAIM TO RIGHT OF PRIORITY

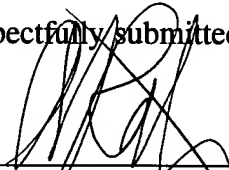
Assistant Commissioner for Patents
Washington, D.C. 20231

S I R :

Pursuant to 35 U.S.C. 119, Applicant's claim to the benefit of filing of prior U. K. Patent Application No. 0020363.8, filed 18 August 2000, as stated in the inventor's Declaration, is hereby confirmed.

A certified copy of the above-referenced application is enclosed.

Respectfully submitted,

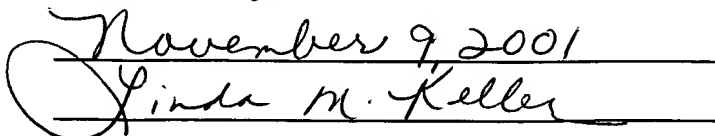

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Enc - Certified Copy of U.K. Application
Dated: November 9, 2001
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Signed

Stephen Hordley

Dated 17th August 2001



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GB0020363.8

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of

SMART STABILISER SYSTEMS LIMITED, Incorporated in the United Kingdom,

14 Ishbourne Way,
Winchcombe,
Cheltenham,
Gloucestershire,
GL54 5NS, United Kingdom

[ADP No. 08054660001]

18 AUG 2000

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent C

Cardiff Road
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SECTION 30 (1977 ACT) APPLICATION FILED 13/12/2000

1. Your reference

P26737-/CMF/PPP

18 AUG 2000

2. Patent application n

(The Patent Office will f

0020363.8

18AUG00 E361914-1 002664

P01/7700 0.00-0020363.8

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Michael Russell
Lynworth House
54 High Street, Prestbury
Cheltenham
Gloucestershire
GL52 3AU

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

7715238001

4. Title of the invention

"Detector Assemblies and Methods"

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Murgitroyd and Company
373 Scotland Street
GLASGOW
G5 8QA

Patents ADP number (if you know it)

1198013

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number
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Date of filing
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

no

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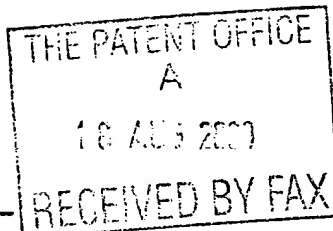
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See note (d))

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Description

14

Claim(s)

-

Abstract

-

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Priority documents

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Statement of inventorship and right to grant of a patent (Patents Form 7/77)

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Any other documents (please specify)

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11.

I/We request the grant of a patent on the basis of this application

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18.8.00

12. Name and daytime telephone number of person to contact in the United Kingdom

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1 "Detector Assemblies and Methods"

2

3 This invention relates to detector assemblies for use
4 principally, but not exclusively, in well logging.

5

6 The latest hydrocarbon production methods require that
7 the production section of the well has a maximum
8 possible length in the oil-bearing stratum. Since most
9 oil-bearing production zones are substantially

10 horizontal, this results in the final section of the
11 well becoming appropriately horizontal. Although the
12 general location of an oil-bearing stratum may be known
13 prior to the drilling of a production well to tap the
14 oil-bearing stratum, the position (in all dimensions)
15 of the production zone is not initially known with
16 sufficient accuracy to ensure that the well can be
17 bored directly to the production zone. Accordingly,
18 geological formation data are collected as the well is
19 drilled, and the collected data are suitably analysed
20 to derive the exact direction (in all three dimensions)

1 along which the well is to be extended, particularly to
2 ensure that the final (and usually horizontal) section
3 of the well is in the best position for the recovery of
4 oil. The procedure is known as "geosteering".

5
6 Geological formation data are commonly gathered by
7 gamma logging, ie by a procedure in which the intensity
8 of detected gamma radiation is utilised to deduce
9 geological properties. (While the source of gamma
10 radiation may be naturally occurring radioisotopes more
11 or less distributed throughout surrounding geological
12 formations, a more usual source of gamma radiation is
13 a manufactured gamma source (eg, a compact mass of
14 cobalt-60) emplaced at a fixed or controllably variable
15 depth in an adjacent well such that the gamma source
16 radiators through the geological formations between the
17 gamma source radiates through the geological formations
18 between the gamma source and a gamma detector in the
19 production well being drilled).

20
21 In order to geosteer, directional logging is necessary.
22 For example, the intensity of detected gamma radiation
23 above the bore of the well being drilled may be
24 compared with the intensity of detected gamma radiation
25 below the bore in order to decide the direction and
26 extent by which to deviate the inclination of the next
27 section of well to be drilled.

28
29 A gamma radiation detector typically comprises an
30 assembly of a gamma-sensitive crystal (which emits a
31 visible photon in response to the impact of a gamma
32 photon), a photomultiplier (which outputs an electrical

1 pulse count proportional to the light output of the
2 gamma-sensitive crystal which, in turn, is proportional
3 to the intensity of incident gamma radiation), and a
4 pulse counter to accumulate a count, over a fixed
5 interval, of electrical pulses from the
6 photomultiplier.

7
8 The gamma radiation detector can be made directionally
9 sensitive by surrounding the gamma-sensitive crystal
10 with a gamma radiation shield (eg, a tungsten shroud),
11 the shield having an aperture or window through which
12 gamma radiation can reach the gamma-sensitive crystal
13 but only from one direction.

14
15 In order to carry out directional gamma logging of the
16 well, it is necessary to orient the shield window to a
17 selected angle with respect to a notional vertical
18 plane through the well bore, and obtain a series of
19 gamma intensity readings at various such angles,
20 thereby to obtain a polar survey of geological
21 formations surrounding the location of the detector.

22
23 In prior art well-drilling operations, the gamma
24 radiation detector was incorporated into a bottom-hole
25 drilling assembly. Directional gamma logging required
26 that normal rotation of the drill string had to be
27 stopped, and the drill string manipulated to orient the
28 window to the required series of angles. The prior art
29 directional logging procedure was therefore
30 time-consuming, and prevented drilling during logging.
31 (Transmission to the surface of logging data was also

1 time-consuming, being usually undertaken by inducing
2 pressure pulses in the drilling mud).

3

4 There is therefore a requirement for a means of
5 conducting well logging operations such as gamma
6 logging during drilling.

7

8 As will be discussed below, gamma logging during
9 drilling requires the establishment of the angular
10 orientation of a downhole assembly about the borehole
11 axis. There are other situations in which knowledge of
12 this angular orientation is desirable, for example in
13 operation of the controllable stabiliser described in
14 EP-A-1024245. The present invention aims to provide a
15 convenient means of doing so.

16

17 According to one aspect of the present invention, there
18 is provided a rotary assembly comprising a rotatable
19 shaft; a sleeve journaled on the shaft and adapted to
20 be stationary during rotation of the shaft; an earth
21 vector sensor mounted for rotation with the shaft, the
22 earth vector sensor being responsive to a given
23 physical parameter in a direction substantially radial
24 to the shaft; and an orientation signal generator which
25 comprises means for generating a pulse train
26 representing rotation of the shaft relative to the
27 sleeve as a predetermined number of pulses per
28 revolution, and means for deriving from the pulse train
29 and the output of the earth vector sensor the angle
30 between the earth vector and a given position on the
31 sleeve.

32

1 Preferably, the rotary assembly is a downhole assembly
2 adapted to form part of a drill string, and the earth
3 vector is the component transverse to the drill string
4 axis in the vicinity of the assembly of the earth's
5 local magnetic field or gravitational field.

6
7 The means for generating a pulse train preferably
8 comprises a directional sensor arranged radially of the
9 shaft and cooperating with a plurality of elements
10 equispaced around the circumference of the sleeve. In
11 a preferred embodiment, said elements are ferromagnetic
12 segments, and the sensor is a coil; the ferromagnetic
13 elements may suitably be 24 in number.

14
15 Said deriving means preferably operates to integrate
16 the earth vector sensor output over each of a number of
17 successive part-revolutions, for example quarter
18 revolutions, of the shaft to provide a series of
19 simultaneous equations, and solving these equations to
20 provide an orientation angle for each of said plurality
21 of elements with respect to the earth vector.

22
23 One embodiment of the first aspect of the invention
24 will now be described, by way of example, with
25 reference to the accompanying drawings, in which:

26
27 Fig. 1 is a schematic cross-section of part
28 of a downhole rotary assembly; and
29 Fig. 2 shows a pulse train produced in the
30 assembly of Fig. 1.

31

6

1 Referring to Fig. 1, a shaft 10 forms part of a
2 downhole assembly. A sleeve 12 is rotatable with
3 respect to the shaft 10. In use, the sleeve 12 engages
4 with a well bore and is rotationally stationary, with
5 the shaft 10 rotating within it.

6
7 The assembly determines orientation by reference to an
8 earth vector E, which is that component of the local
9 earth magnetic field or local earth gravity acting at
10 right angles to the shaft axis.

11
12 The assembly includes an earth vector sensor 14 mounted
13 on the shaft for rotation therewith. The earth vector
14 sensor 14 is a sensor for measuring the amplitude of
15 the earth magnetic field or gravity along a rotating
16 axis OX radial to the shaft.

17
18 The sleeve 12 is provided with a number (in this
19 embodiment twenty four) of equally circumferentially
20 spaced ferromagnetic segments 16, which cooperate with
21 a pick-off coil 18 mounted on the shaft 10. The pick-
22 off coil 18 is arranged, in this embodiment, to detect
23 along the same axis OX as the vector sensor 14 but
24 could be arranged on a different radius of the shaft 10
25 as long as the angle between the two detector axes is
26 known.

27
28 The pick-off coil 18 produces a pulse train P0 - P24 as
29 illustrated in Fig. 2. The outputs of the earth vector
30 sensor 14 and the pick-off coil 18 are processed as
31 will now be discussed. It will be apparent to those in
32 the art that the signal processing to be described can

1 be effected by readily available electronic circuits or
2 computers.

3

4 **EARTH VECTOR SENSOR OUTPUT**

5

6 If the (constant) angular velocity of the rotating
7 shaft is W then

8 $W = d(S)/dt$

9

10 If time = 0 when (OX) is aligned with the Earth Vector
11 Reference Direction (OE), then the Shaft Orientation
12 Angle at any subsequent time t is given by

13

14 $S = \int_0^t W \cdot dt = W \cdot t$

15

16 0

17 and the Segment n Orientation Angle $S_n = W \cdot t_n$

18

19

20 If the period of rotation of the drill string is T then

21 $T = 2\pi/W$

22

23 With reference to Figure 1, the magnitude of the sensed
24 vector along the sensing axis direction (OX) at time t
25 can be written as

26

27 $E_x(t) = E \cdot \cos(W(t)) + E_k$

28

29 where E is the magnitude of the Earth Reference Vector
30 $\{E\}$ and E_k is a constant term provided that W is
31 constant.

8

1
2 Thus, the sensing transducer output at time t can be
3 written as

4
5 $V_x(t) = V \cdot \cos(W \cdot t) + V_k$

6
7 where V_k is a constant term combining the transducer
8 bias and the term E_k . $V = SF \cdot E$ where SF is the
9 transducer scale factor (volts/g).

10

11 EARTH VECTOR SENSOR OUTPUT INTEGRATIONS

12

13 If Pulse P_0 of figure 1 is an arbitrarily chosen pulse
14 at some time t_0 the repeated pulses P_0 , P_6 , P_{12} and P_{18}
15 associated with times t_0 , $t_0 + T/4$, $t_0 + T/2$, $t_0 + 3T/4$
16 respectively are used to control the integration of the
17 sensing transducer output $V_x(t)$ over 4 successive
18 quarter periods of rotation starting at time t_0 .

19

20 Consider the Integration of $V_x(t)$ from any initial time
21 t_1 to $t_1 + T/4$

22

23 $t_1 + T/4$ $t_1 + T/4$
24 $Q = \int_{t_1}^{t_1 + T/4} V \cdot \cos(W \cdot t) \cdot dt + \int_{t_1}^{t_1 + T/4} V_k \cdot dt$
25 t_1 t_1

26

27

28

29

30

31

9

1

2 Thus,

3

$$t_1 + T/4$$

4

$$Q = [(V/W) \cdot \sin(W \cdot t)] + V_k \cdot T/4$$

5

$$t_1$$

6

7

8

$$Q = (V/W) \cdot [\sin(W \cdot t_1 + W \cdot T/4) - \sin(W \cdot t_1)] + K$$

9

or

$$Q = (V/W) \cdot [\sin(W \cdot t_1 + \pi/2) - \sin(W \cdot t_1)] + K$$

11

or

$$Q = (V/W) \cdot [\cos(W \cdot t_1) - \sin(W \cdot t_1)] + K \quad \text{..... (i)}$$

13

Where K is a constant = $V_k \cdot T/4$

14

15 Using equation (i), the integration of $V_x(t)$ from time
16 t_0 to time $t_0 + T/4$ yields

$$Q_1 = (V/W) \cdot [\cos(W \cdot t_0) - \sin(W \cdot t_0)] + K \quad \text{..... (ii)}$$

18

19 Using equation (i), the integration of $V_x(t)$ from time
20 $t_0 + T/4$ to time $t_0 + T/2$ yields

21

$$Q_2 = (V/W) \cdot [\cos(W \cdot t_0 + W \cdot T/4) - \sin(W \cdot t_0 + W \cdot T/4)] + K$$

23

24 or

25

$$Q_2 = (V/W) \cdot [\cos(W \cdot t_0 + \pi/2) - \sin(W \cdot t_0 + \pi/2)] + K$$

27

28 or

29

$$Q_2 = (V/W) \cdot [-\sin(W \cdot t_0) - \cos(W \cdot t_0)] + K \quad \text{..... (iii)}$$

31

10

1 Using equation (i), the integration of $V_x(\tau)$ from time
 2 $\tau_0 + T/2$ to time $\tau_0 + 3T/4$ yields

3

$$4 \quad Q_3 = (V/W) \cdot [\cos(W \cdot \tau_0 + W \cdot T/2) - \sin(W \cdot \tau_0 + W \cdot T/2)] + K$$

5

6 or

7

$$8 \quad Q_3 = (V/W) \cdot [\cos(W \cdot \tau_0 + \pi) - \sin(W \cdot \tau_0 + \pi)] + K$$

9

10 or

11

$$12 \quad Q_3 = (V/W) \cdot [-\cos(W \cdot \tau_0) + \sin(W \cdot \tau_0)] + K \quad \text{..... (iv)}$$

13

14 Using equation (i), the integration of $V_x(\tau)$ from time
 15 $\tau_0 + 3T/4$ to time $\tau_0 + T$ yields

16

$$17 \quad Q_4 = (V/W) \cdot [\cos(W \cdot \tau_0 + W \cdot 3T/4) - \sin(W \cdot \tau_0 + W \cdot 3T/4)] + K$$

18

19 or

20

$$21 \quad Q_4 = (V/W) \cdot [\cos(W \cdot \tau_0 + 3\pi/2) - \sin(W \cdot \tau_0 + 3\pi/2)] + K$$

22

23 or

24

$$25 \quad Q_4 = (V/W) \cdot [\sin(W \cdot \tau_0) + \cos(W \cdot \tau_0)] + K \quad \text{..... (v)}$$

26

27 Writing $K_1 = V/W$ and $\alpha = W \cdot \tau_0$ then equations (ii)
 28 through (v) yield for the four successive integrations
 29 of $V_x(\tau)$

30

$$31 \quad Q_1 = -K_1 \cdot \sin \alpha \quad + \quad K_1 \cdot \cos \alpha \quad + K \quad \text{..... (vi)}$$

11

$$\begin{array}{llllll}
 1 & Q_2 = -K_1 \sin \alpha & - & K_1 \cos \alpha & +K & \dots (vii) \\
 2 & Q_3 = K_1 \sin \alpha & - & K_1 \cos \alpha & +K & \dots (viii) \\
 3 & Q_4 = K_1 \sin \alpha & + & K_1 \cos \alpha & +K & \dots (ix)
 \end{array}$$

4

5 ROTATION ANGLES

6

7 Equations (vi) through (ix) can be solved to yield
 8 angle α ; there is a degree of redundancy in the
 9 possible solutions but, for example,

10

$$11 \quad Q_1 - Q_2 = 2K_1 \cos \alpha$$

12

13 and

14

$$15 \quad Q_3 - Q_2 = 2K_1 \cos \alpha$$

16

17 or

18

$$19 \quad \sin \alpha / \cos \alpha = (Q_3 - Q_2) / (Q_1 - Q_2) \quad \dots (x)$$

20

21 Since $\alpha = W.t_0$ then α is the angle S_0 between (OE) and
 22 the radius through the segment which activates pulse P_0 ,
 23 or the angle between (OX) and (OE) at the time t_0 when
 24 P_0 occurs, it follows that when Pulse P_n occurs at time
 25 t_n the angle between (OX) and (OE) is

26

$$27 \quad S_n = \alpha + n.2\pi/24 \quad \dots (xi)$$

28

29 Thus, the segment orientation angles S_n for each
 30 segment are known and the corresponding pulses can be

12

1 used to control events at known 15 degree ($2\pi/24$)
2 rotating shaft orientation angles.

3
4 The foregoing embodiment may be incorporated in a
5 controllable stabiliser apparatus as described in
6 EP-A-1024245 to provide an orientation reference. In
7 such use, the embodiment described may have an
8 additional function. In EP-A-1024245 a controlled
9 eccentricity is produced between the shaft 10 and the
10 sleeve 12. By examining not only the timing but also
11 the amplitude of the pulses P0 - P24, the amount of
12 eccentricity at any time can be determined.

13
14 The present invention in another aspect provides a
15 well-logging procedure comprising the steps of
16 providing a directional well-logging means in a bottom-
17 hole assembly, the directionality of the logging means
18 being substantially synchronous with rotation of the
19 bottom-hole assembly, providing direction sensing means
20 in the bottom-hole assembly for sensing the
21 instantaneous direction of the bottom-hole assembly and
22 hence of the well-logging means, providing a respective
23 logging data reception means for each direction for
24 which well logging is to take place, and switching the
25 output of the well-logging means between appropriate
26 ones of the logging data reception means according to
27 the instantaneously sensed direction of the bottom-hole
28 assembly whereby to accumulate directional logging data
29 during rotation of the bottom-hole assembly.

30

13

1 The well-logging procedure may comprise the further
2 step of subsequently transmitting accumulated
3 directional logging data to the surface by utilising a
4 data transmission means that does not require cessation
5 of rotation of the bottom-hole assembly.

6
7 The invention in this further aspect may also be
8 defined in terms of well-logging equipment comprising a
9 rotatable bottom-hole assembly including a directional
10 well-logging means whose directionality is
11 substantially synchronous with rotation of the bottom-
12 hole assembly, direction sensing means for sensing the
13 instantaneous direction of the bottom-hole assembly and
14 hence of the well-logging means, a respective logging
15 data reception means for each direction for which well
16 logging is to take place, and switching means for
17 switching the output of the well-logging means between
18 appropriate ones of the logging data reception means
19 according to the instantaneously sensed direction of
20 the bottom-hole assembly.

21
22 The bottom-hole assembly may further comprise data
23 transmission means capable of selectively transmitting
24 accumulated directional logging data to the surface,
25 the data transmission means preferably not requiring
26 cessation of rotation of the bottom-hole assembly.

27
28 The directional well-logging means may comprise a
29 directionally sensitive gamma logger which is mounted
30 within the bottom-hole assembly and is mounted
31 non-rotatably with respect thereto. The gamma logger
32 may be rendered directionally sensitive by being

14

1 shrouded by a gamma radiation shield having a gamma
2 radiation transmitting aperture therein.

3

4 The direction sensing means may comprise a
5 geomagnetically sensitive magnetometer means operable
6 to provide substantially instantaneous values for the
7 bearing and azimuth of the bottom-hole assembly.

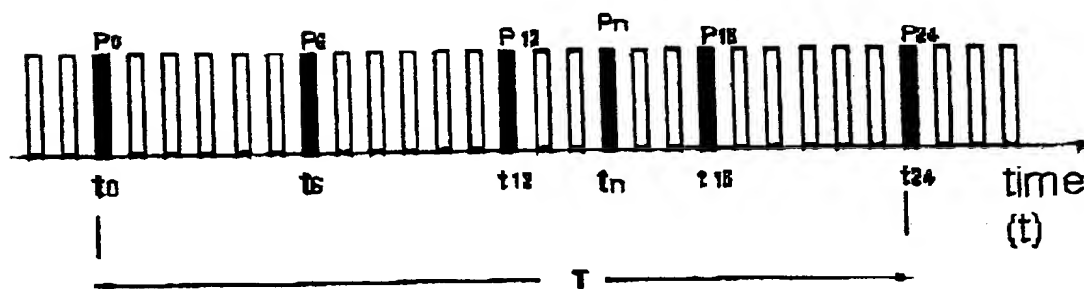
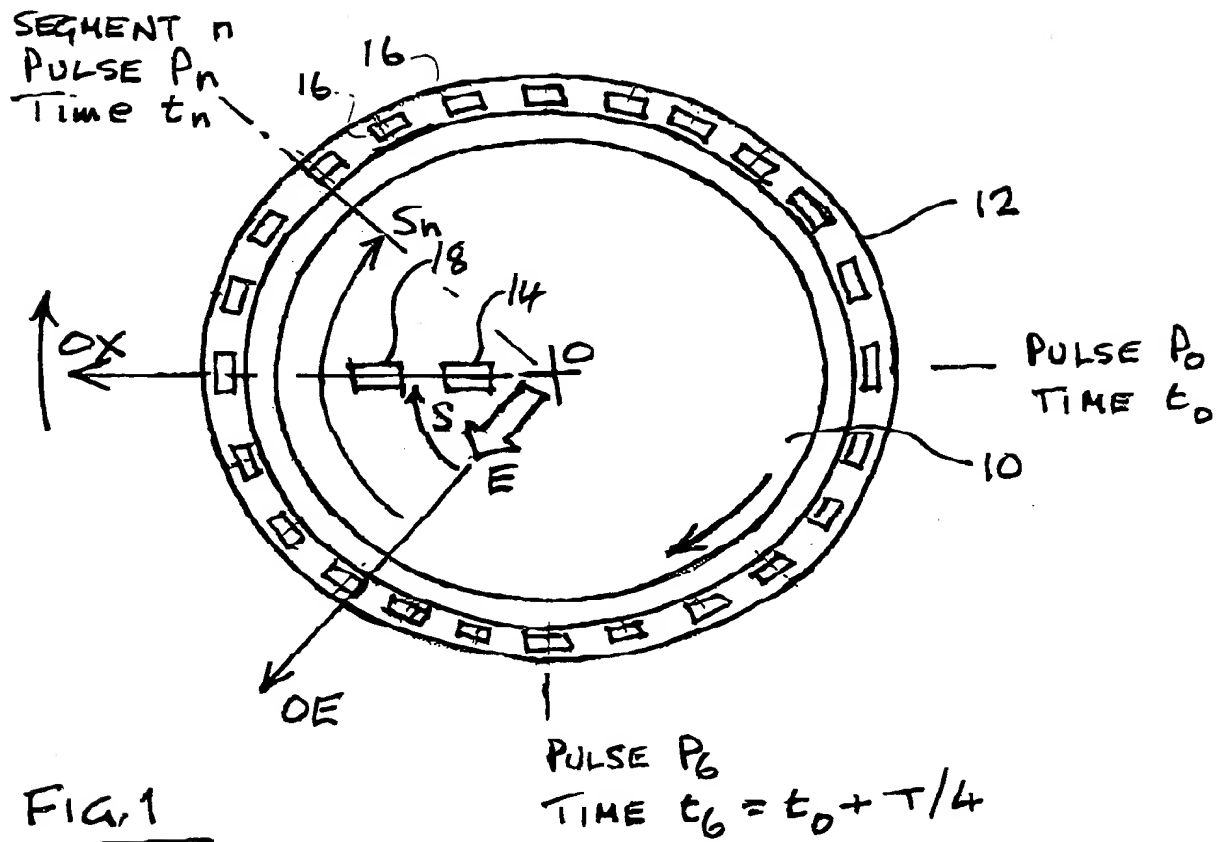
8

9 The well-logging equipment according to the second
10 aspect of the present invention may be incorporated
11 into a directionally-controlled eccentric as described
12 in [EP.A.1024245], preferably as part of the
13 directionally-sensitive control system 18 of the
14 exemplary embodiment as described with reference to
15 Fig. 1 of [EP.A.1024245].

16

17 Modifications and improvements of the above-described
18 embodiments can be adopted without departing from the
19 scope of the invention.

20



POSITION PICK-OFF PULSE TRAIN

FIG. 2

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